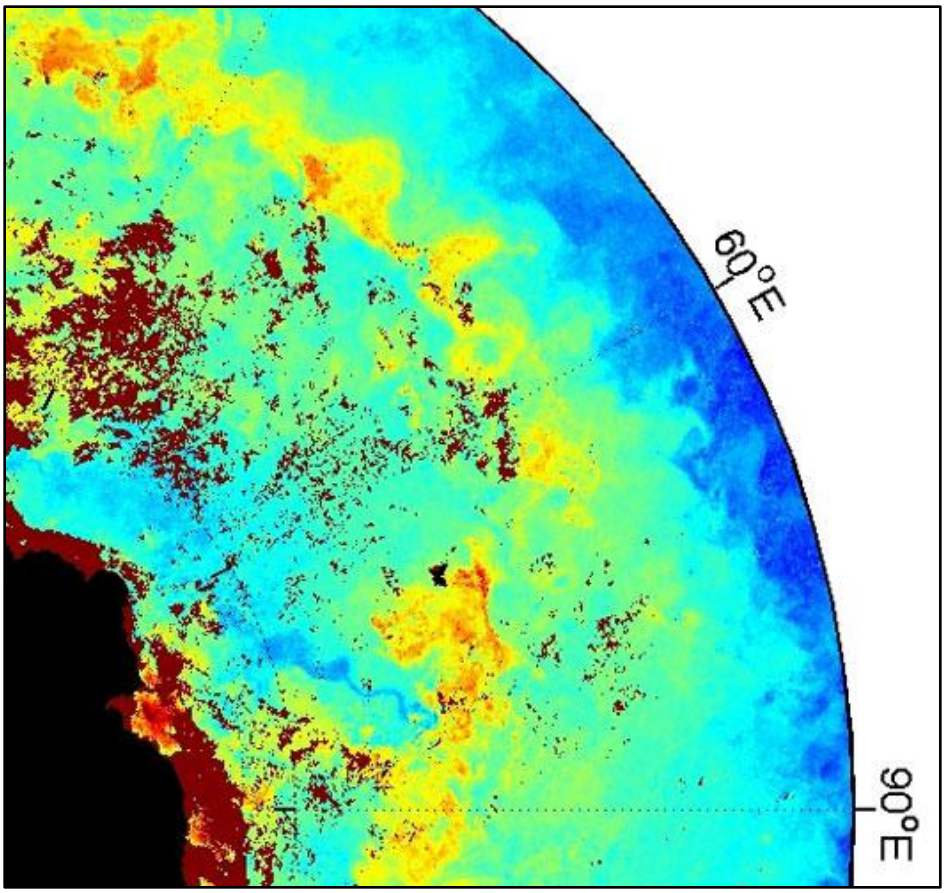
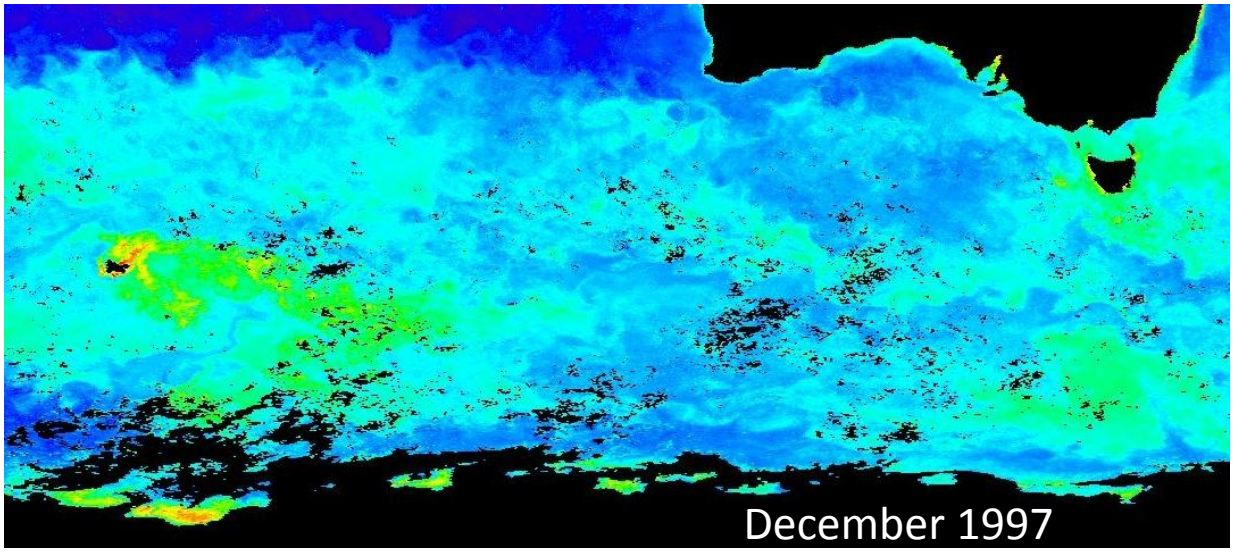
SCIENCE FOCUS: The Southern Ocean

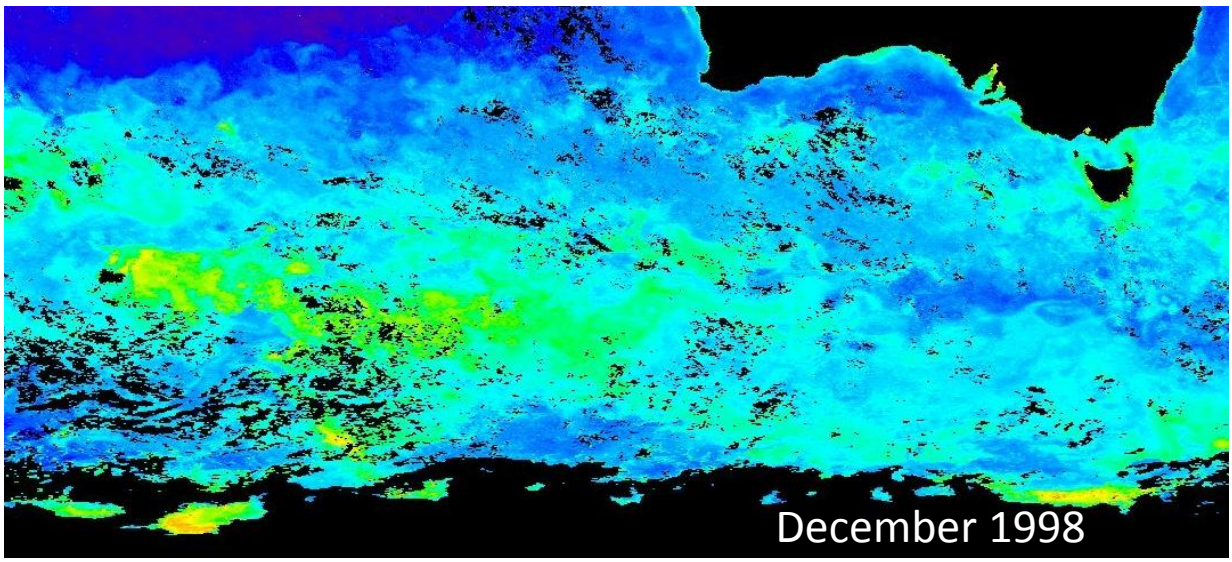
The Low Zone (A *Science Focus*! Inquiry Study)

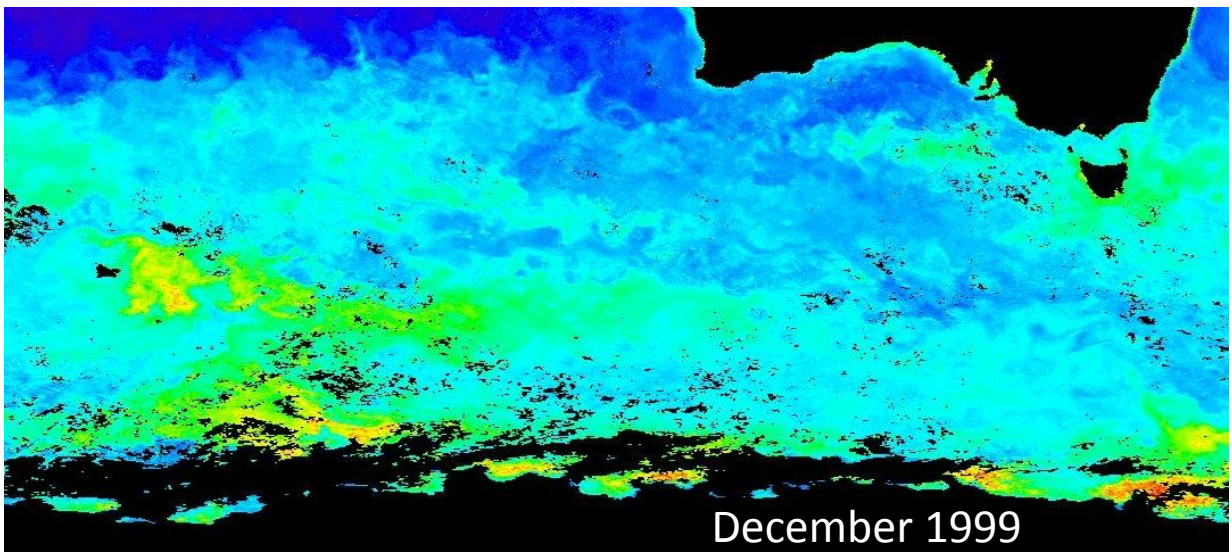
The image below was sent to us by Matt Reuer of Princeton University as part of an inquiry about the use of SeaWiFS data in a particular software package. When we looked at this image, we were immediately intrigued by the sinuous area of low productivity that appears north of the Antarctic continent [well, everything is north of the Antarctic continent] between 60 and 90 east latitude. We called this area "The Low Zone". (Note that the false-color palette used to generate the image is different than the standard palette used by the SeaWiFS Project.)

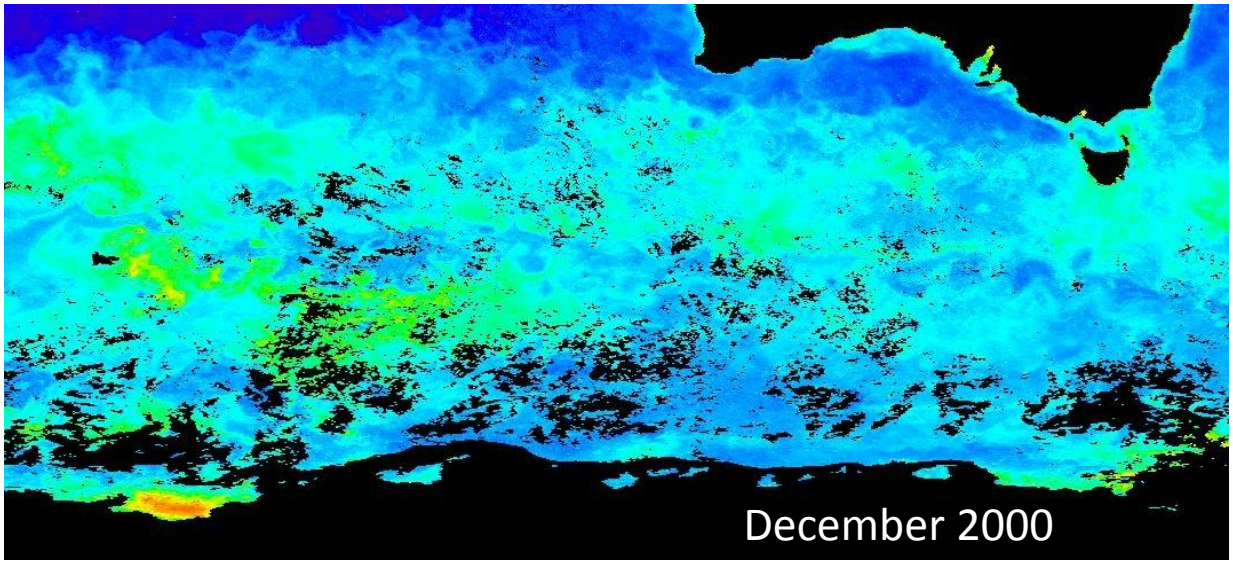


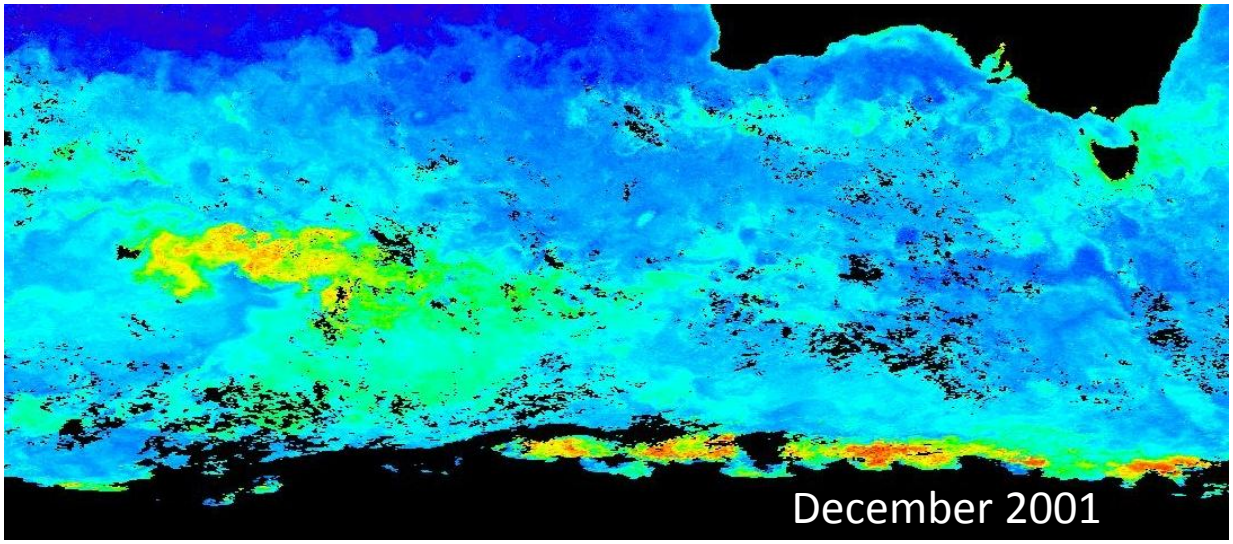
When we then examined SeaWiFS monthly Level 3 images for each of the months of December since the beginning of the mission, we realized that this area of low productivity is a definite feature of the circulation of the Southern Ocean. This initial examination undermined some of our more fanciful hypotheses, such as the possibility that this area was the track of a large tabular iceberg. On the next pages are extracts from the SeaWiFS monthly December images for this area from December 1997 to December 2003.

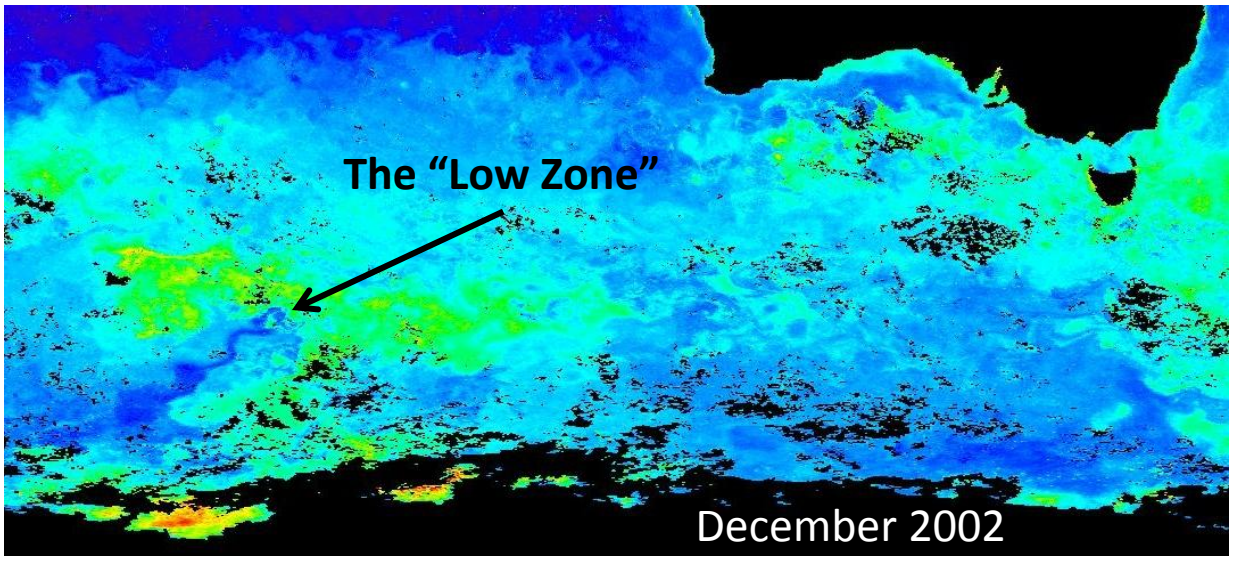

December 1997

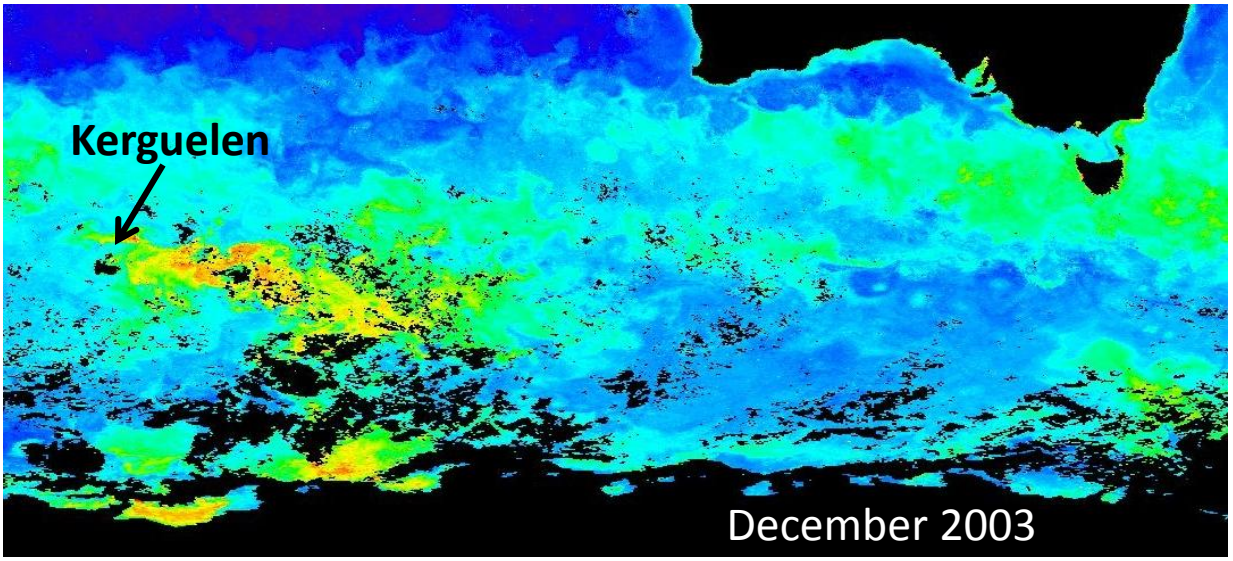

December 1998


December 1999


December 2000


December 2001


The “Low Zone”
December 2002



On re-examination, it appears that this feature is due to the circulation of the Antarctic Circumpolar Current (ACC) around the relatively shallow Kerguelen Plateau. The island of Kerguelen is the small and isolated black spot that appears on the far western side of each image, about halfway between the top and bottom. The island is definitely associated with nearly elevated chlorophyll concentrations.

The Inquiry Study: What we did in March 2004 was to solicit explanations of the cause of the "Low Zone" from the oceanographic community. The Web version of this article was released at the end of February 2004. During that time, members of the oceanographic community were invited to send explanations (and any accompanying imagery or graphics) describing as simply and completely as possible what is happening here. As part of the explanation, we thought it would be interesting to know:

- What are the basics of the interaction between physical oceanography (ocean circulation) and biological activity in this region?
- Is there a specific reason that "The Low Zone" appears particularly well-defined in December 2002, and is significantly less visible in other years, such as December 2000?
- Why are the chlorophyll concentrations so much higher and the productive region larger in December 2003?
- Are there any other areas in the world ocean where a similar phenomenon occurs, or is this area unique?

Contributions to "The Low Zone" were gratefully received from Michel Rixen (NATO/SACLANT Undersea Research Centre), Johann Lutjeharms (Department of Oceanography, University of Cape Town), and Raymond Pollard (Southampton Oceanography Centre).

Rixen indicated that the "Low Zone" appears to be a frontal instability that is generated by horizontal pressure gradients within the ACC system. Instabilities generate mesoscale fronts that provide nutrients to the surface, and which therefore generate increased primary production. This mechanism is likely responsible for the generation of the persistent "downstream" elevated region of productivity, i.e., the region to the east of Kerguelen that extends to an area south of western Australia.

Lutjeharms comments on one of the primary features of the biological system in the Southern Ocean, which Pollard expanded upon. Lutjeharms and colleagues have been conducting research in the Prince Edward Islands, which are located to the west of the Kerguelen and Crozet archipelagos. Productivity here, as well as in the oceanic waters near Kerguelen, is limited by the availability of iron. This makes the general Southern Ocean a "high nutrient low chlorophyll (HNLC)" region, as noted by Pollard. Lutjeharms suggests, noting that more research is required, that the Prince Edward Islands and Kerguelen may generate "island effect" productivity by providing a source of iron to the adjacent waters. Lutjeharms notes that one possible source of iron is the fresh water runoff, which passes through the droppings of millions of seabirds, thus possibly supplying iron and other nutrients in a low-salinity buoyant plume of water that would stay near the surface and enhance productivity.

Pollard provided additional information on the characteristic HNLC nature of Southern Ocean waters. The "Low Zone" is not unique; other areas (such as the Bellingshausen Sea) are also characterized by low productivity. Thus, the "Low Zone" is an area where the low productivity waters around Antarctica are being transported northeastward in the ACC system, and the low chlorophyll concentration contrasts markedly with the higher productivity waters north of them. Therefore, like Lutjeharms, Pollard indicates that the focus of research is on the generation of the higher productivity regions near the islands.

Pollard's preferred explanation, which will be investigated by two upcoming research expeditions (see below) is that the iron is derived from the seafloor, brought to the surface in shallow waters due to turbulent mixing processes in the water column.(Interestingly, this is the same explanation for the extended plume of productivity near the Galapagos archipelago in the tropical Pacific Ocean.) The "Low Zone" is an oceanic region where the local bathymetry—otherwise known as the depth of the water—is too deep to bring iron to the surface, according to Pollard.

Now a bit more information on the currents around Kerguelen: NOAA Technical Memorandum NMFS-AFSC-6 describes a survey of cetacean habitat in the Southern Ocean. The southeast edge of the Kerguelen Plateau was a popular area for both sperm and minke whales, and 50% of humpback whale sightings were also associated with the Kerguelen Plateau. The underlying physical oceanography which makes this region popular with cetaceans is due to the interaction of the Southern Front of the ACC and the southern water mass boundary [Southern Boundary] of the ACC. (The Southern Front is at the surface, while the southern water mass boundary is subsurface.) In this region, the Southern Boundary moves to higher latitudes, and causes warm, nutrient rich waters of the Upper Circumpolar Deep Water (UCDW) to reach the surface mixed layer, partly due to interaction with the Kerguelen Plateau. The result is increased productivity by phytoplankton (diatoms), which are consumed by krill (euphausid zooplankton), which are eaten by whales—and thus the Kerguelen Plateau is where the whales are.

Link:

KEOPS: Kerguelen: Compared study of the Ocean and the Plateau in Surface water

Kerguelen Island

Kerguelen Island is one of the last great relatively unexplored locations in the world. This is due partly to its isolation, as it can only be reached by ship. It is also due to the harsh weather that it is characteristic of the region. There is a small French research station on the island, but the island is mainly home to penguins, seals, and elephant seals. (There is even an elephant seal crossing sign at the research station.) The author of this article was very fortunate to visit the research station on Kerguelen Island during a research and supply cruise in February 1985 on the first R/V *Marion Dufresne*.

Kerguelen is still an active volcanic province; expeditions to the interior have discovered fumaroles and hot springs.

Links

Archipel des Kerguelen (SPOT image mosaic)

Parcours A Kerguelen par Bertrand Moine
Note: These pictures, first linked to this article on the Web in 2004, are still available, though they are small. There are a lot more pictures of Kerguelen on the Web now than there were in 2004!

The *Marion Dufresne II* Research Vessel

Flickr gallery of the first R/V *Marion Dufresne*

Three pictures of the first R/V *Marion Dufresne:*